

Clothing, Insulation, and Climate

Turn off all electronic devices

Observations about Clothing, Insulation, and Climate

- Clothing keeps you warm in cold places
- Clothing can keep you cool in very hot places
- Insulation controls heat flow in various objects
- Insulation can be obvious, as in foam cups
- Insulation can be subtle, as in special windows
- Greenhouse gases trap heat and warm the earth

4 Questions about Clothing, Insulation, and Climate

1. How does clothing control thermal conduction?
2. How does clothing control thermal convection?
3. How does insulation control thermal radiation?
4. Why do greenhouse gases warm the earth?

Question 1

- Q: How does clothing control thermal conduction?
 A: Via low-conductivity materials and small temperature gradients

Law governing conductive heat flow through a material:

$$\text{heat flow} = \frac{\text{conductivity} \cdot \text{temperature difference} \cdot \text{area}}{\text{thickness}}$$

Insulation suppresses conductive heat flow based on that law:

- Uses low-conductivity materials include insulators and air
- Your body naturally acts to reducing temperature differences
- Uses increased thickness to provide greater insulation
- You and your clothing limits exposed area reduces heat flow

Question 2

- Q: How does clothing control thermal convection?
 A: It suppresses the movement of air

The rate of convective heat flow depends on

- the fluid's heat capacity and mobility
- the temperature difference between hot and cold
- how well the fluid circulates from hot to cold

Clothing suppresses convective heat flow by:

- trapping air in finely divided materials
- reducing your surface temperature
- blocking wind-based or motion-based forced convection (wind chill)

Question 3

- Q: How does insulation control thermal radiation?
 A: Via low-emissivity materials and reduced temperature differences

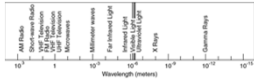
Thermal radiation obeys the Stefan-Boltzmann law:

$$\text{power} = \text{emissivity} \cdot \text{Stefan-Boltzmann constant} \cdot \text{temperature}^4 \cdot \text{surface area}$$

- where emissivity measures emitting-absorbing efficiency, from 0 to 1
- Insulation suppresses radiative heat flow by
- using low-emissivity (white, clear, shiny) materials
 - using multiple layers

Thermal Radiation

A black surface's thermal radiation depends only on its temperature
 Hotter surfaces radiate shorter wavelength electromagnetic waves

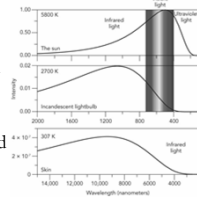


A black surface emits a black body spectrum

- The sun emits a 5800K black body spectrum
- A lightbulb emits a 2700K black body spectrum
- Objects hotter than about 500 °C glow visibly
- Your skin emits a ~307K black body spectrum

Most things (e.g., skin) are black in the infrared

- They have “low-temperature” emissivities of 1



Question 4

Q: Why do greenhouse gases warm the earth?

A: They increase the altitude of earth's effective radiating surface

Earth absorbs and emits equal amounts of thermal radiation

- Earth receives thermal radiation from the sun
- Earth emits thermal radiation into space
- To balance, Earth's radiating surface must be -18 °C

The atmosphere is involved in that exchange of thermal radiation

- Earth's effective radiating surface is about 5 km above sea level
- Greenhouse gases increase altitude of that surface

Earth's surface temperature

- depends on the altitude of its radiating surface
- increases as the altitude of its radiating surface increases

Effects of the Atmosphere

Earth's atmosphere has a natural temperature gradient

- air expands and cools as its altitude increases
- air temperature decreases 6.6 °C per km of altitude

Atmosphere's average temperature

- at 5 km is -18 °C (Earth's effective radiating surface and temperature)
- at sea level is 15 °C (where people live)

Effects of Greenhouse Gases

Greenhouse gases “darken” the atmosphere

- Low-temperature emissivity of atmosphere increases
- Effective radiating surface moves to higher altitude
- Average temperature at sea level increases

Increasing greenhouse gases cause global warming

Greenhouse gases include

- water, carbon dioxide, nitrogen oxides, and methane
- not nitrogen or oxygen, which are transparent in the infrared

Limiting greenhouse gases is critical to our future

Summary about Clothing, Insulation, and Climate

Clothing and insulation limit heat transfer

They use materials with low thermal conductivities

They introduce drag to impede convection

They use low emissivities to reduce radiation

Greenhouse gases affect Earth's thermal radiation

Those gases raise Earth's surface temperature